# Plants for Stormwater Pollution Removal

Greenhouse Research and Field-Study at Green Meadows Subdivision

Logan, UT

Utah Water Research Laboratory, USU

Cache Valley Stormwater Coalition, JUB Engineering, June 28, 2012

## Presentation Outline

- Introduction
- Greenhouse
- Green Meadows
- Cost Savings

# Introduction

# Protecting Stormwater

- Much of the stormwater protection in Cache Valley is done with respect to prevention of TSS contamination during construction activities
- Preventing contamination of stormwater from construction activities is critical, but stormwater can still be highly polluted

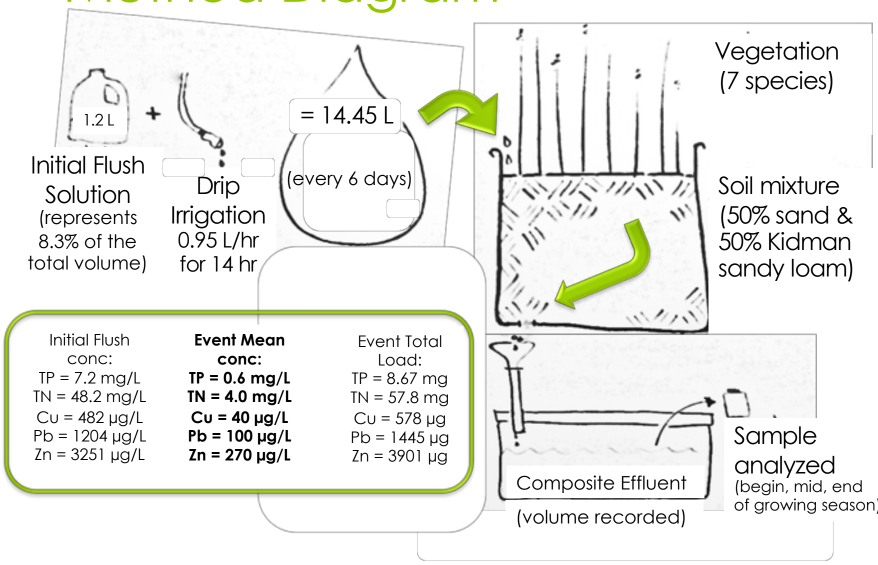
# Hypotheses

- Some plant species remove more N and/or P from runoff than other species
- Harvesting plant material can remove N and/or P from the site and keep it from entering downstream water bodies

# Greenhouse Experiment

## Greenhouse

# Method Diagram




| Initial Flush conc: | **Event Mean conc:** | Event Total Load: |
|---|---|---|
| TP = 7.2 mg/L | **TP = 0.6 mg/L** | TP = 8.67 mg |
| TN = 48.2 mg/L | **TN = 4.0 mg/L** | TN = 57.8 mg |
| Cu = 482 µg/L | **Cu = 40 µg/L** | Cu = 578 µg |
| Pb = 1204 µg/L | **Pb = 100 µg/L** | Pb = 1445 µg |
| Zn = 3251 µg/L | **Zn = 270 µg/L** | Zn = 3901 µg |

## Seven BMP species

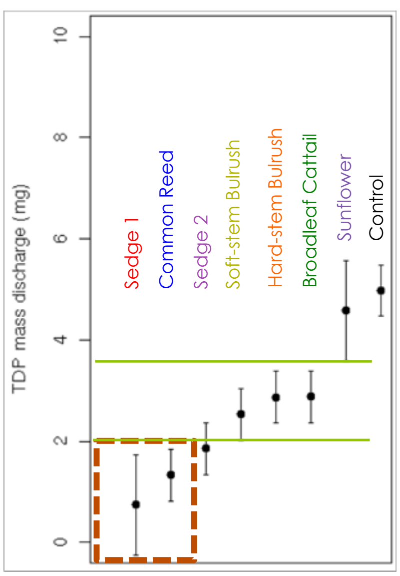
Greenhouse

# Harvest

- Harvest of Above and Below Ground plant material occurred after 6 months of growth
- Plant material weighed, dried, ground and analyzed for N&P and metals

Greenhouse

## TDP mass discharge

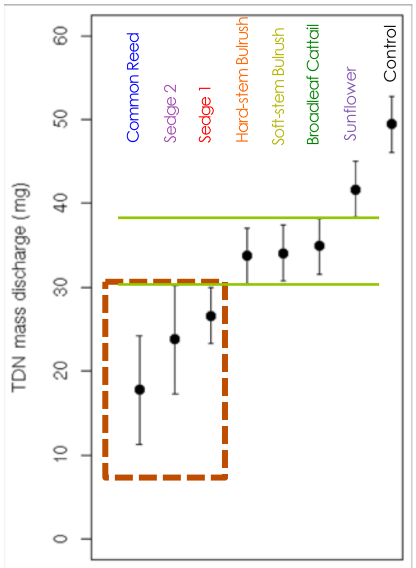



Mean values with 95% C.I.

Event Total Load:
**TP = 8.67 mg**
TN = 57.8 mg
Cu = 578 μg
Pb = 1445 μg
Zn = 3901 μg

## Greenhouse

### TDN mass discharge



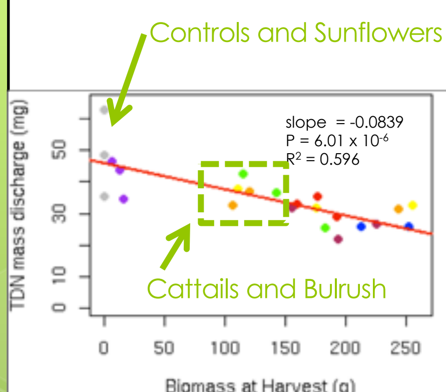

Mean values with 95% C.I.

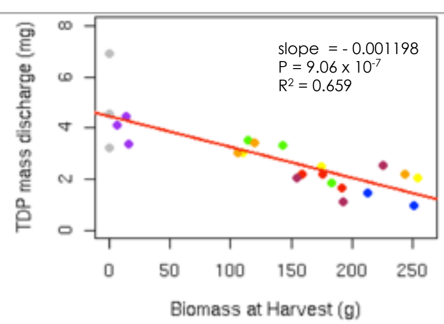
Planted samples have lower TDN & TDP mass discharge than controls and sunflower*

Event Total Load:
TP = 8.67 mg
**TN = 57.8 mg**
Cu = 578 µg
Pb = 1445 µg
Zn = 3901 µg

## Greenhouse

### TDN & TDP vs. Biomass



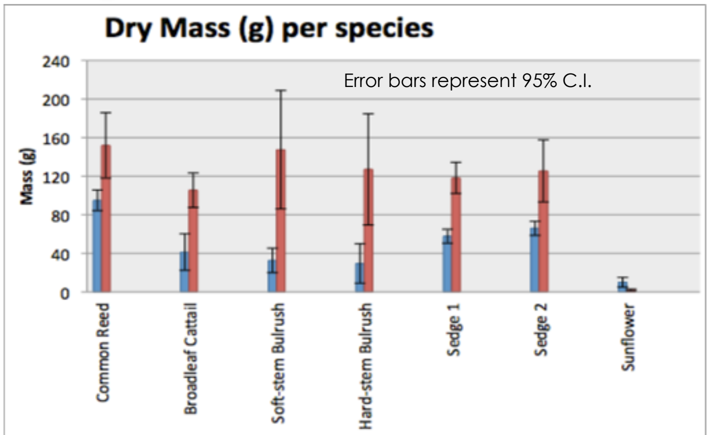




Increased biomass yields lower N & P mass discharge in effluent water

## Greenhouse

### Plant biomass

Legend
Above Ground
Below Ground

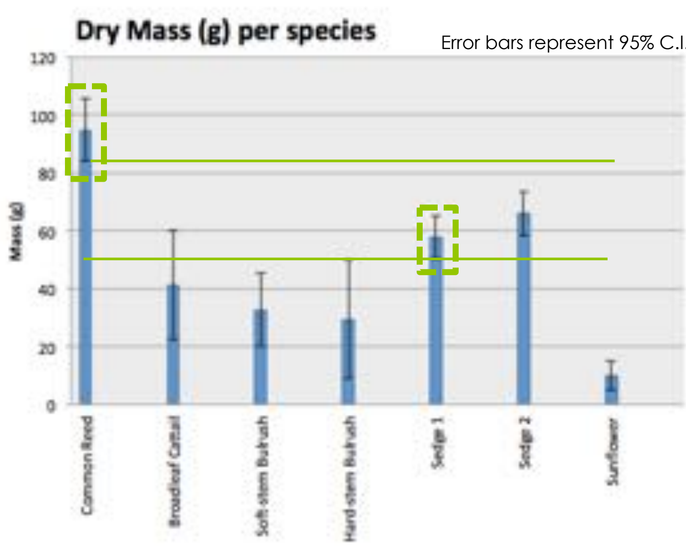



There is significantly more below ground (root) mass than above ground (leaf) mass.

*Only the above ground mass can be harvested.

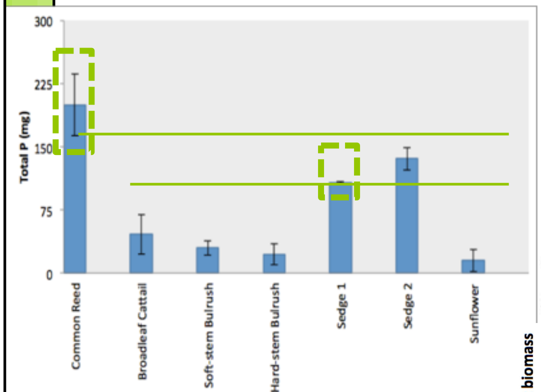
## Greenhouse

### Above Ground Biomass



## Greenhouse

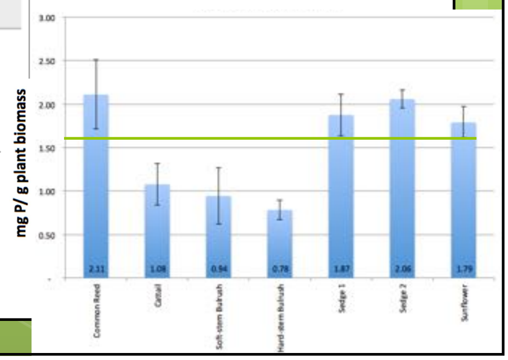
### Total P in Above Ground Biomass




Mass In:

32 rain events *14.45 L
* 0.6 mg/L

=277 mg P

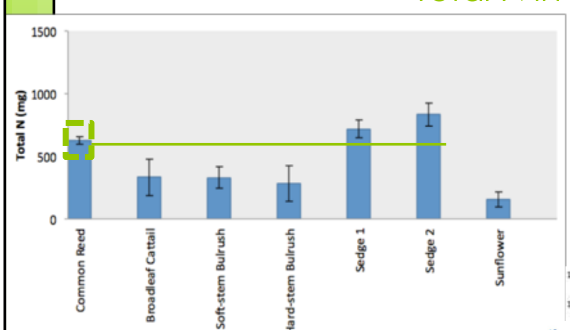



Common Reed removes the most P in the above ground material.

Error bars represent 95% C.I.

## Greenhouse

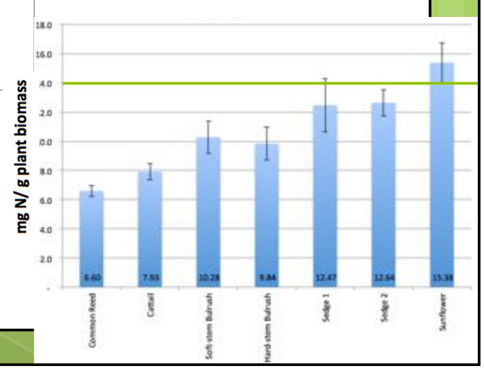
### Total N in Above Ground Biomass




Mass In:

32 rain events
*14.45 L
*4 mg/L

=1,850 mg N



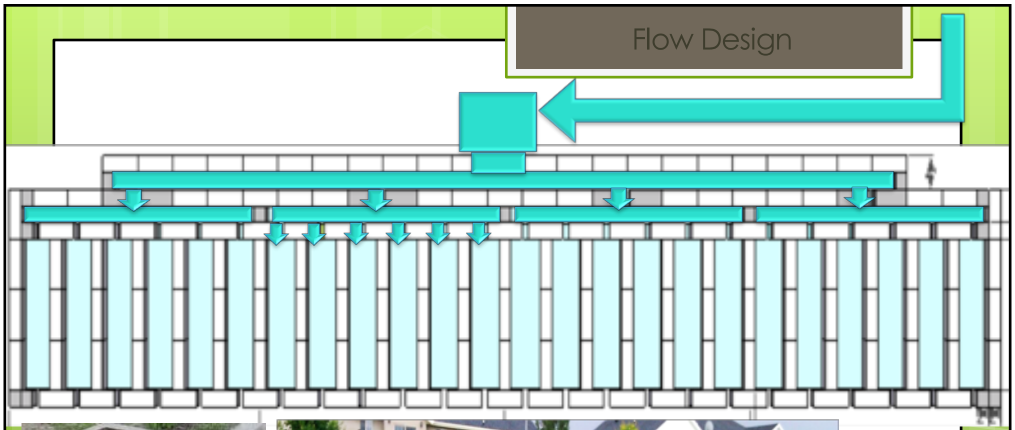

Common Reed and Sedges remove more N mass than the other species

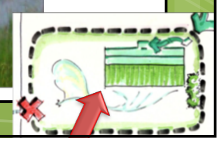
Error bars represent 95% C.I.

# Green Meadows Field Site

## Field Site

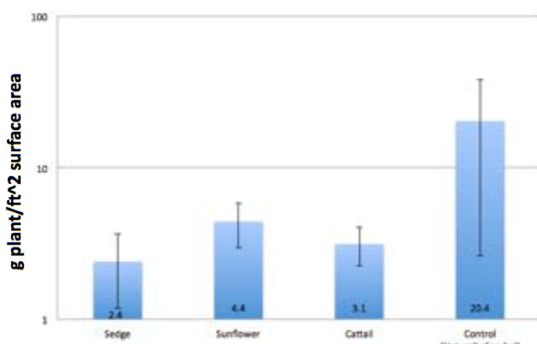
## Flow Design





## Field Site

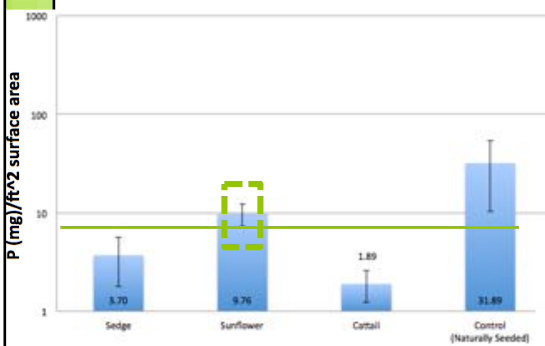
### Biomass per ft$^2$ (1$^{st}$ year of growth)

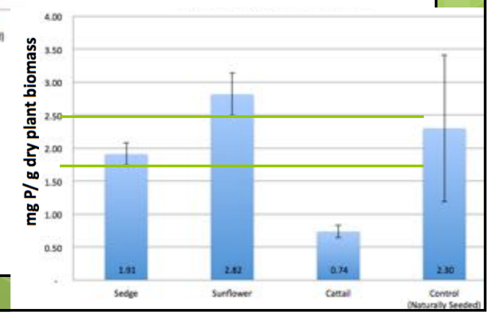



Naturally seeded treatment had visually more growth, yet there is no significant difference in biomass production among treatments

## Field Site

### Total P in Above Ground Biomass



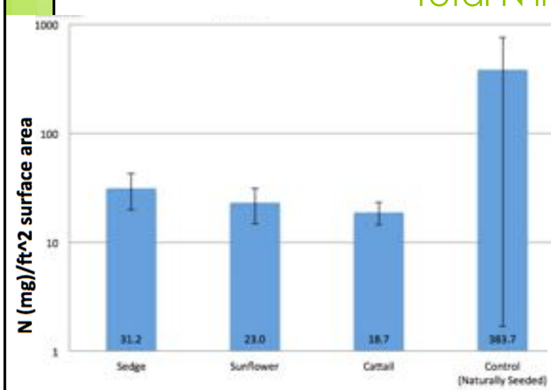



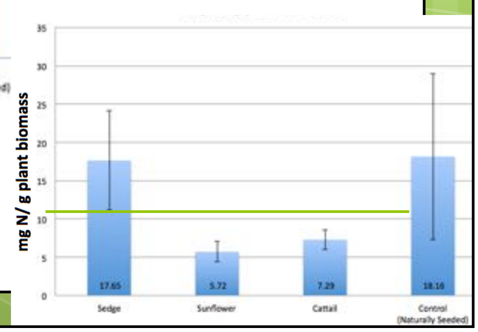

Sunflower and Control show a significantly higher P removal than Sedge and Cattail

Error bars represent 95% C.I.

## Field Site

### Total N in Above Ground Biomass




There is no significant difference in N removal among the treatments

Error bars represent 95% C.I.

# Cost Savings

15' x 5' bay

Typical BMP =3% of developed land
(1,900 $m^2$ vegetated area)

## Typical BMP

### Money saved by avoiding Chemical N&P removal

| | Kilograms of Hazardous materials Reduced (by biomass only) | | | | | |
|---|---|---|---|---|---|---|
| | P2 Efforts (for first growing season of Field Site Study): | Dry Biomass Production (kg) | Pollutant Removed (kg) | Total (kg) | Dollars Saved | |
| | Vegetative Stormwater Detention Basins (based on Field Site data) | | | | | |
| | Typical BMP (1,900 m^2 active growing area) | | | | | |
| C | **Sedge B (*Carex microptera*)** | 49.2 | 0.64 N | 0.73 | $125 | N&P Removal |
| | | | 0.091 P | | $6.82 | Compost |
| H | **Sunflower (*Helianphus maximillian*)** | 90.4 | 0.47 N | 0.71 | $122 | N&P Removal |
| | | | 0.24 P | | $12.52 | Compost |
| T | **Broadleaf Cattail (*Typha latifolia*)** | 64.3 | 0.38 N | 0.43 | $74 | N&P Removal |
| | | | 0.05 P | | $8.90 | Compost |
| X | Control (Naturally Seeded) | 416.4 | 7.85 N | 8.63 | $1,481 | N&P Removal |
| | | | 0.78 P | | $57.68 | Compost |

Control (naturally seeded) treatment produces the greatest N & P Removal cost savings and Compost cost benefits during the **first growing season**

Typical BMP =3%
(1,900 m$^2$)


3% of developed land in Cache County
(1,965,000 m$^2$)

## Basin Wide

### Money saved by avoiding Chemical N&P removal

**Kilograms** of Hazardous materials Reduced (by biomass only)

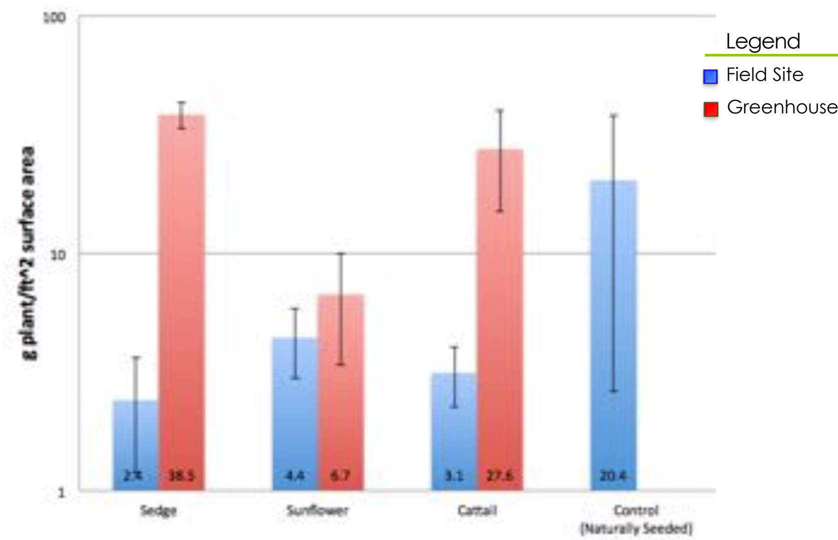
| | P2 Efforts (for first growing season of Field Site Study): | Dry Biomass Production (kg) | Pollutant Removed (kg) | Total (kg) | Dollars Saved | |
|---|---|---|---|---|---|---|
| | Vegetative Stormwater Detention Basins (based on Field Site data) | | | | | |
| | Basin Wide (1.9E6 m^2) | | | | | |
| C | **Sedge B (*Carex microptera*)** | 50334.7 | 652 N | 745.4 | $127,905 | N&P Removal |
| | | | 93 P | | $6,972 | Compost |
| H | **Sunflower (*Helianphus maximillian*)** | 92378.8 | 482 N | 726.5 | $124,670 | N&P Removal |
| | | | 245 P | | $12,796 | Compost |
| T | **Broadleaf Cattail (*Typha latifolia*)** | 65691.1 | 392 N | 439.2 | $75,362 | N&P Removal |
| | | | 48 P | | $9,099 | Compost |
| X | Control (Naturally Seeded) | 425723.9 | 8022.2 N | 8822.5 | $1,513,937 | N&P Removal |
| | | | 800.2 P | | $58,971 | Compost |

## Biomass Images


July 11, 2011


June 12, 2012

## Growth Comparison




Field Site vs. Greenhouse

## Preliminary Conclusions

- Some Plants (sedge and sunflower) have higher concentrations in their biomass and are better at removing N and/or P than others.
- Biomass production is a key factor!
- Proposed site design parameters for BMPs:
  - Plant and maintain more vegetation!
  - Irrigate BMPs to promote growth of desired species for desired pollutant removal
  - Harvest vegetation and remove off-site ***before*** leaves begin to shoot nutrients back into their roots

## Next Steps

Green Meadows:

- Collect more influent data to compare to EPA estimates
- Collect and analyze 2nd year plant data
- Harvest in mid season to promote greater biomass growth and analyze mid-season vs. end of season harvest results.

## Questions?

Funded by: Utah Mineral Lease Fund
In kind matching: Logan City

Special THANKS to:

| | |
|---|---|
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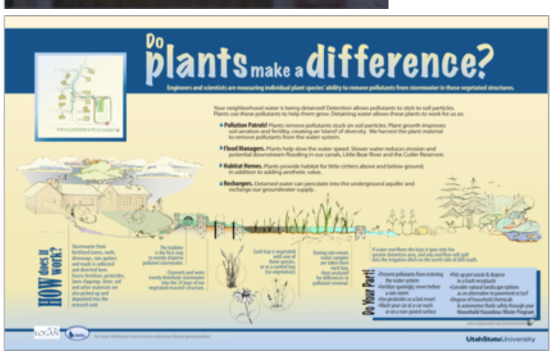
| A. Restad | T. Guy |
| A. Lewis | A. Abu-Ramaileh |




## Event Mean Concentration Comparison

Event Mean conc:
TP = 0.6 mg/L
TN = 4.0 mg/L
Cu = 40 µg/L
Pb = 100 µg/L
Zn = 270 µg/L

Greenhouse
(EPA's regional values)

Event Mean conc:
TDP ≈ 0.105 mg/L
TDN ≈ 1.84 mg/L
Cu ≈ 8.9 µg/L
Pb = BDL
Zn ≈ 92.5 µg/L

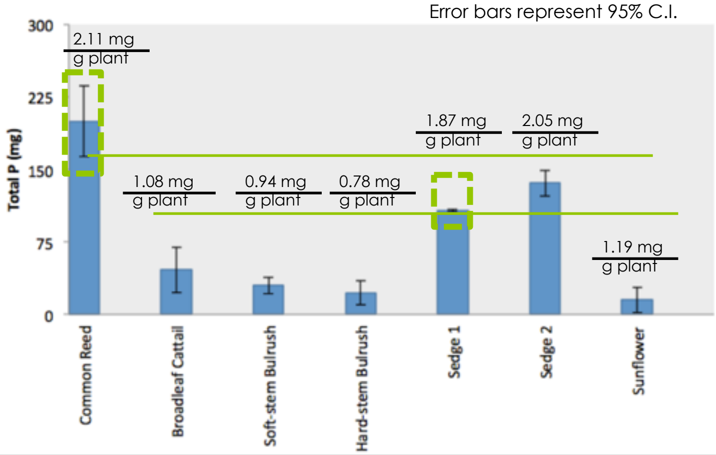
Field Site

Initial Flush conc:
TP = .25 mg/L
TN = 4.05 mg/L
Cu = 8.91 µg/L
Pb = BDL
Zn = 164.5µg/L

Greenhouse

## Total P in Above Ground biomass

Error bars represent 95% C.I.




Mass In:

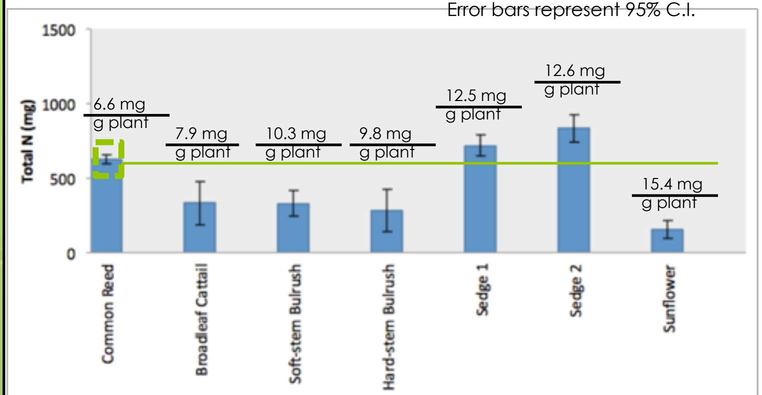
32 rain events *14.45 L
* 0.6 mg/L

=277 mg P

Common Reed removes the most P in the above ground material

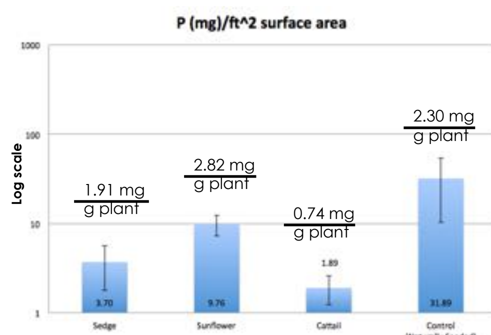
## Greenhouse

### Total N in Above Ground Plant biomass




## Field Site

### TP removed by biomass

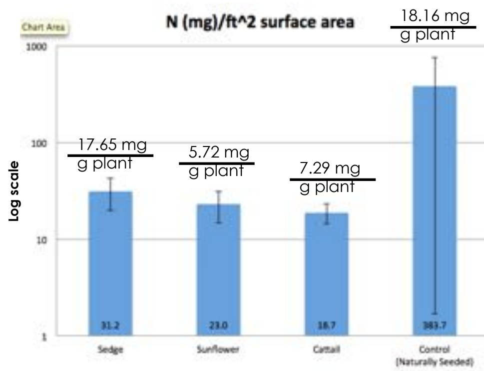



| **mg P / g plant** | **Sedge** | **Sunflower** | **Cattail** |
|---|---|---|---|
| Field Site | 1.91 | 2.82 | 0.74 |
| Greenhouse | 1.96 | 1.19 | 1.08 |

Error bars represent 95% C.I.

## Field Site

### TN removed by biomass




| mg P / g plant | Sedge | Sunflower | Cattail |
|---|---|---|---|
| Field Site | 17.65 | 5.72 | 7.29 |
| Greenhouse | 12.55 | 15.4 | 7.9 |

Error bars represent 95% C.I.

## Stormwater in Utah

- Utah has 2nd highest population growth in nation
- Large increases in P and N discharged into downstream water bodies from untreated stormwater runoff

## Stormwater in Utah

- Cutler Reservoir is included in Utah's "Impaired Waters" list and is required to be part of Utah's TMDL process (Wilbur 2009)
- Mean seasonal total P concentrations are limited to 0.075 mg/L at Cutler Dam outfall (UDEQ, 2009)

## Protecting Stormwater

- Cutler Reservoir is included in Utah's "Impaired Waters" list and is required to be part of Utah's TMDL process (Wilbur 2009)
- Mean seasonal total P concentrations are limited to 0.075 mg/L at Cutler Dam outfall (UDEQ, 2009)

# What is in stormwater?

- Runoff from urbanized areas, agricultural lands, fertilized lawns, roofs, driveways, rain gutters, roads, etc. that flows into a downstream water body without treatment

# Traditional management approach

- Collect and convey water off site as quickly as possible

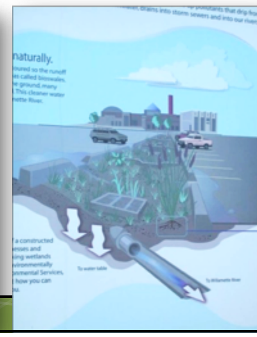
- Collection in concentrated points of discharge generate high velocity and high volumes of flow

**Images: WERF 11-15-06 Presentation** (Wenk Associates, Conservation Design Forum, Meyer/Reed, and Barr Eng.)

# What is a BMP?

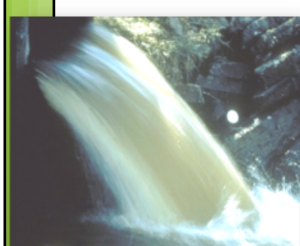
- BEST MANAGEMENT PRACTICES (BMP's): activities, prohibitions of practices, maintenance procedures, and other practices (such as **on-site structures**) to prevent or reduce the **pollution** of waters of the United States
- BMP's also include **practices to control site runoff**, spillage or leaks





# National stormwater regulations

- EPA's NPDES require large and medium municipalities (including Logan) to include BMPs as a part of new developments (US EPA 2006)
- This includes building on-site structural stormwater BMPs



## Structural stormwater BMPs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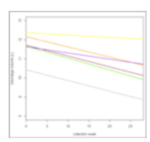
# Structural stormwater BMPs

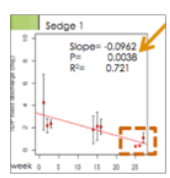
- Plants are often used to aid in the removal of pollutants

# Conclusion

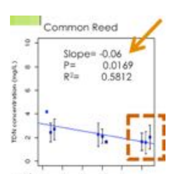
- **Volume** of water discharged is reduced over the growing season



- Sedge 1 saw lower **concentrations** and **mass** discharges of P, and **mass** discharge of N over time




- Common Reed saw lower **concentrations** and **mass** discharges of N over time



# Conclusion

- Controls had significantly higher P concentrations and mass discharge than all planted totes (except sunflower)
- Controls had significantly higher N concentrations and mass discharge than **all** planted totes
- Some species had significantly lower concentrations and mass discharge of N and P than other species
- N and P **concentration** and **mass** discharge decreases with total biomass production